# NRL Gulf of Mexico SeaWiFS Bio-Optical Data Sets

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*ABSTRACT*

The Naval Research Laboratory has initiated the Gulf of Mexico Bio-Optical Data Sets to produce long-term data sets that have been processed in a consistent manner for Gulf of Mexico bio-optical change research and for algorithm development especially in Case-2 turbid waters. The Gulf of Mexico SeaWiFS Bio-Optical data sets are regional data mapped to a 1 km Mercator projection of the Gulf of Mexico. The data consist of remote sensing reflectances derived from the eight-channel cross-track scanning SeaWIFS aboard the Orbital Sciences' Orbview-2 satellite along with derived bio-optical parameters (chlorophyll-a, diffuse attenuation, absorption and scattering parameters, etc.), cloud and quality control indicators, and ancillary data. The data are being produced from the NASA High Resolution Picture Transmission (HRPT) data collected routinely by the NRL receiving station and spanning a period of more than 2-years (1997-present). The data set is archived locally at the Naval Research Laboratory at Stennis Space Center

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## 1. Data Set Overview:

### 1.1. Data Set Identification:

NRL Gulf of Mexico SeaWiFS Bio-Optical Data Set

### 1.2. Data Set Introduction:

The Gulf of Mexico presents a diverse bio-optical environment for testing new ocean algorithms. The loop current and tropical waters near and around Cuba are optically deep. The tea-like waters in the Florida panhandle are rich in DOM. There are clear bottom reflective regions in Florida Bay. The Mobile

Bay and Mississippi Sound regions are high in suspended sediments.

The Gulf of Mexico Bio-Optical Data Set, initiated by NRL, produces long-term data sets processed in a consistent manner for regional change research and Case-2 algorithm development. The Gulf of Mexico SeaWiFS Bio-Optical data sets are produced from more than 2 years of archived data from the eight-channel SeaWiFS sensor aboard the Orbview-2 satellite,

The measured reflected radiation provide direct geophysical information of the water surface. The data also contain bio-optical data derived from the visible channel reflectances, a highly correlated parameter to surface chlorophyll-a concentration. Cloud and quality control indicators identify water surface areas where measured variables are degraded.

The Gulf of Mexico SeaWiFS Bio-Optical data are Level 3 products (regionally mapped data). There are 2 main types of products, Daily Data Set and Browse Images.

### 1.3. Objective/Purpose:

The objective of producing the NRL Gulf of Mexico SeaWiFS Bio-Optical Data Sets is to provide long-term, regional data of water surface parameters with high temporal frequency and high resolution for studying the behavior of Case-2 algorithms in the the Gulf of Mexico.

### 1.4. Summary of Parameters:

The Gulf of Mexico Bio-Optical data set consists of geophysical parameters projected to a 1km Mercator map projection of the Gulf of Mexico. The geophysical parameters consist of six remote sensing refletances (reflectance data corrected for atmospheric light scattering and sun angles differing from nadir), and 27 geophysical parameters derived from the radiance data.

The Daily data sets contain the following 32 parameters:

| | |
|---|---|
| 1-6 | Remote Sensing Reflectances at 412, 443, 490, 510, 555, 670 |
| 7 | Chlorophyll-a concentration using Carder's algorithm |
| 8 | Chlorophyll-a concentration SeaBAM's OC2 algorithm |
| 9 | Chlorophyll-a concentration Stumpf's GOM algorithm |
| 10 | Diffuse Attenuation at 532 |
| 11 | Beam Attenuation at 670 |
| 12-17 | Total Absorption at 412, 443, 490, 510, 555, 670 (Carder) |
| 18-23 | Total Absorption at 412, 443, 490, 510, 555, 670 (Arnone) |
| 24 | Detris and Gelbstoff Absorption at 412 (Carder) |
| 25 | Detris and Gelbstoff Absorption at 412 (Stumpf) |
| 26 | Phytoplankton Absorption at 443 (Carder) |
| 27 | Phytoplankton Absorption at 443 (Stumpf) |
| 28-29 | Backscattering at 443, 555 (Carder) |
| 30-31 | Backscattering at 443, 555 (Arnone) |
| 32 | Albedo at 865 nm |
| 33 | Quality Check flag |

The Daily Browse Image contains 11 parameters:

| | |
|---|---|
| 1-2 | Chlorophyll-a concentration (SeaBAM, Stumpf) |
| 3 | Diffuse Attenuation at 532 |
| 4-5 | Total Absorption at 443 (Arnone,Carder) |
| 6-7 | Detris and Gelbstoff Absorption at 412 (Carder,Stumpf) |
| 8-9 | Phytoplankton Absorption at 443 (Carder,Stumpf) |
| 10-11 | Backscattering at 555 (Arnone,Carder) |

## 2. Investigator(s):

### 2.1. Investigator(s) Name and Title:

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### 2.2. Title of Investigation:

NRL Gulf of Mexico SeaWiFS Bio-Optical Data Sets.

### 2.3. Contact Information:

See above.

## 3. Theory of Measurments:

Ocean color remote sensing is based on the principle that particulate and dissolved substances suspended in water will interact with incident light. Where concentrations of particulate matter and dissolved substances are low, conditions typical for the open ocean, water molecules scatter light similar to the way that the atmosphere scatters light, producing a characteristic deep blue color. The scattering of light by particulates and the absorption of light by dissolved substances will alter this color. Chlorophyll, the photosynthetic pigment found in phytoplankton, absorbs strongly in the red and blue regions of the visible light spectrum and reflects in the green. As the concentration of phytoplankton increases, the color of the water will therefore appear increasingly green. The absorption of light by chlorophyll can be quantified to determine the concentration of chlorophyll in water, allowing estimation of phytoplankton abundance in a given area.

The relationship between light absorption and chlorophyll concentration may be complicated by the presence of light-scattering inorganic particulate matter in the water. Particulate matter concentrations generally increase in coastal regions, such that the water color near the coast trends from green to brown or reddish-brown. Even though chlorophyll may be present in higher concentrations near the coast, the presence of particulate matter makes it more difficult to extract the amount of light absorption due solely to chlorophyll. In addition, certain classes of phytoplankton form hard mineral shells that scatter light very effectively, such that the water color can appear shade of aquamarine or milky white.

SeaWiFS measures light intensity in several bands. The measurements allow quantification of light absorption and subsequent estimation of chlorophyll and suspended matter concentrations. SeaWiFS improves on the CZCS mission by having better bands for atmospheric correction (i.e., removing the effect of light scattering by the Earth's atmosphere), which will particularly aid the estimation of chlorophyll and suspended matter in coastal regions.

## 4. Equipment:

### 4.1. Sensor/Instrument Description:

The OrbView-2 satellite (formerly called "SeaStar") orbits in a sun-synchronous, descending node orbit at an altitude of 705 km. The orbital period is 98.9 minutes, with an inclination of 98.217 degrees. Local time of descending node is 12:05 PM + 15 minutes. The satellite was launched on August 1, 1997 into a 305 km orbit, and 32 orbit-raising burns performed over the next month raised the orbit to its final altitude.

The satellite has a three-axis stabilized system consisting of orthogonal magnetic torque rods for roll and yaw control and two momentum wheels for pitch stabilization. The satellite is equipped with sun sensors, horizon sensors, and magnetometers.

The propulsion system consists of two subsystems, a reaction control system and a hydrazine propulsion system. The reaction control system uses nitrogen and provides third stage stabilization during the launch. The hydrazine propulsion system is used for raising the orbit from the nominal 278 km parking orbit to the 705 km sun- synchronous operational orbit. In addition, it is used for orbit trim requirements over the life of the mission. The spacecraft employs four Hamilton Standard one pound thrusters.

Redundant global positioning system (GPS) receivers are used for orbit determination, an essential component of satellite and data navigation (Earth location). The orbit state derived from GPS is included in the spacecraft health telemetry.

Two telemetry streams are transmitted. The first is real-time LAC data merged with spacecraft health and instrument telemetry at 665.4 kbps. This is transmitted at L-band with a frequency of 1702.56 MHz. The other telemetry stream consists of stored GAC and selected LAC, along with spacecraft health and instrument telemetry, at 2.0 Mbps. This is transmitted at S-band with a frequency of 2272.5 MHz. The command system uses S-band with an uplink of 19.2 kbaud at 2092.59 MHz.

### 4.2. Source/Platform Mission Objectives:

The primary mission objective of SeaWiFS and the Orbview-2 satellite is to obtain a continuous five-year record of ocean radiance observations.

### 4.3. Key Variables:

Reflective radiation.

### 4.4. Principles of Operation:

Remote sensing instruments measure electromagnetic energy that is either reflected or emitted from objects and surfaces. This measurement technique can be termed either radiometry or photometry, depending on the wavelength range of the energy being measured. Radiometry refers to measurement of electromagnetic radiation, ranging from X-rays to radio waves. Photometry refers specifically to measurement of energy in the human optical wavelength range. The terms "spectral radiometry" or "spectral photometry" refer to measurements of energy defined per unit of wavelength.

### 4.5. Manufacturer of Sensor/Instrument:

Santa Barbara Research Center (SBRC)

## 5. Calibration:

### 5.1. Specifications:

Pre-Launch Calibration

Due to the stringent radiometric objectives of the SeaWiFS Project, SeaWiFS underwent an extensive prelaunch calibration program. Calibration was performed at Hughes SBRC, and included an open air observation of the Sun for solar calibration purposes. (The preflight solar calibration is described in Chapter

3 of Volume 19 in the SeaWiFS Technical Report Series, NASA Technical Memorandum 104566.) The prelaunch characteristics of SeaWiFS were analyzed in detail to provide a comprehensive understanding of the sensor's radiometric response. SBRC employed a 100cm Spherical Integrating Source (SIS) which with a spectral shape equivalent to a 2,850 K blackbody for calibration purposes. Despite the approximate three-year hiatus between instrument completion and spacecraft integration, the calibration of the instrument was essentially unchanged over that time.

For further information, see Volume 22 of the SeaWiFS Prelaunch Technical Report Series, "Prelaunch Acceptance Report for the SeaWiFS Radiometer".

| | |
|---|---|
| Tolerance | IFOV, nadir, zero tilt: 1 - 1.21 km |
| Fore and aft pointing | 0, +20, -20 deg, 40 degree tilt change within 30s |
| Band tolerances | Band edges +/- 2 nm, stable to less than 1 nm |
| Out-of-band response | Less than 5% of within-band value for 100% reflectance |
| Band co-registration | Co-registration within 0.3 pixel |
| Sensitivity | SNRs to exceed: Band 1, 499, Band 2, 674, Band 3, 667, Band 4, 640, Band 5, 596, Band 6, 442, Band 7, 455, Band 8, 467. |
| Absolute radiometric accuracy | 5% |

### 5.2. Frequency of Calibration:

SeaWiFS does not carry calibration lamps, but will rely on views of a solar radiation diffuser and the moon for radiometric calibration. The solar radiation diffuser is viewed once per orbit (near the southern terminator) to monitor sensor calibration over several orbits. The moon is viewed via a spacecraft maneuver to monitor calibration over months or years. Lunar views take place when the lunar phase is few days prior to or past full moon.

### 5.3. Other Calibration Information:

Data validation is accomplished by comparing data from the sensor to ocean optical data obtained during a series of calibration cruises, both prelaunch (commencing in 1992) and soon after the launch of the satellite. The data validation process also utilizes data from the Marine Optical Buoy (MOBY) moored off of the island of Lanai, Hawaii. MOBY is a moored in- and above-water optical radiometer that can transmit data to a receiving station on Lanai, allowing frequent comparison to data from SeaWiFS.

### 5.4. Time Depedent Corrections:

The time correction calibration table for the latest (June 1999) round of vicarious calibrations is used for the Gulf of Mexico Bio-Optical Data Set (SEAWIFS_SENSOR_CAL.TBL-199909_time_dep_7jun99). This table includes a single linear time correction for each of bands 1, 2, 5, and 6, in addition to the 3 piecewise linear corrections to bands 7 and 8. The radiometric responses of bands 1 and 6 have gone down by approximately 0.75% over 650 days. The response of band 2 has gone down by approximately 0.45% and the response of band 5 has gone down by approximately 0.22%. The calibration table corrects these changes in the response of bands 1, 2, 5, and 6.

A description of the technique used to determine the time correction to the various bands is available here: "Lunar Phase Angle Effects in the SeaWiFS Measurements of the Moon", Robert A. Barnes, Draft version submitted to the SeaWiFS post launch TM series.

## 6. Data Description:

SeaWiFS data consists of ocean radiances in 8 spectral bands and derived geophysical products.

### 6.1. Spatial Characteristics:

### 6.1.1. Spatial Coverage:

Spatial coverage is daily. Coverage is slightly degraded during parts of the year due to instrument tilt to avoid sun glint effects.

### 6.1.2. Spatial Resolution:

| | |
|---|---|
| Daily Data Sets | 1km Mercator projection |
| Browse Daily Data Sets | Approximately 5km Mercator projection |

### 6.2. Projection:

Mercator projection with the following parameters:

| | |
|---|---|
| Datum | Clarke 1866 |
| Longitude of Central Meridian | -89.000000 |
| Latitude of True Scale | 22.000000 |
| Semi-Major Axis | 6378206.400000 |
| Semi-Minor Axis | 6356583.800000 |
| Image Width | 2430 |
| Image Heigth | 1810 |
| NW Latitude | 31.000000 |
| NW Longitude | -98.000000 |
| SE Latitude | 18.818087 |
| SE Longitude | -80.014815 |
| Center Latitude | 25.068626 |
| Center Longitude | -89.014815 |

### 6.3. Temporal Characteristics:

### 6.3.1. Temporal Coverage:

Daily coverage from September 18, 1997 to present. There are several periods in which no data was collected:

| | |
|---|---|
| July 10, 1998 | SeaWiFS in safe-haven. |
| November 16, 1998 to November 21, 1998 | SeaWiFS in safe-haven (Leonids) |
| January 1, 1998 to January 2, 1999 | SeaWiFS in safe-haven. |
| February 3, 1999 | SeaWiFS in safe-haven. |
| November 16, 1999 to November 18, 1999 | SeaWiFS in safe-haven. |

### 6.3.2. Temporal Resolution:

Daily.

## 7. Data Format

All Gulf of Mexico SeaWiFS Bio-Optical data is available in Hierarchical Data Format (HDF), a data format developed by the National Center for Supercomputing Applications (NCSA). HDF is a "self-describing" data format, which means that all of the information necessary to examine the data in an HDF file is contained within the file.

HDF has several different "data models" which are used to store data products. The data models that are used to store data are Scientific Data Sets (SDS), Raster Image Sets, Vgroups, and Vdatas. Global

Attributes contain data that is applicable to the entire data file. An entire HDF file may be visualized schematically as a set of objects containing different data variables. Vgroups act as directories to data arrays, and they can contain SDS objects. Vdatas are list objects with data organized into fields within each Vdata, where each field is identified by a unique field name.

### 7.1. HDF Structure of Gulf of Mexico SeaWiFS Bio-Optical Data:

Each Gulf of Mexico SeaWiFS Bio-Optical data file consists of 38 Scientific Data Sets each with their own attributes and 41 Global Attributes. 32 of the SDS(s) contains the data for each one of the 32 Level 3 geophysical parameters. Four of the SDS's contain navigation information and the last SDS is called "History" but was unimplemented by the software (other than its creation!).

#### 7.1.1. Global Attributes:

There are 41 global or "file" attributes which pertain to all the SDS's in a given data set. These attributes describe time information, the sensor parameters, data set creation, location, and input parameters.

Information about file creation:

| | |
|---|---|
| createTime | Time of file creation. |
| createSoftware | "APS v2.4" |
| createAgency | "Naval Research Laboratory, Stennis Space Center" |
| createPlatform | "i686-pc-linux-gnu" |

Information about the sensor/platform characteristics:

| | |
|---|---|
| sensor | "SeaWiFS" |
| sensorAgency | "Orbital Sciences, Inc." |
| sensorType | "scanner" |
| sensorSpectrum | "visible" |
| sensorNumberOfBands | 8 |
| sensorBandUnits | "nano meters" |
| sensorBands | [ 412.0, 443.0, 490.0, 510.0, 555.0, 676.0, 750.0, 850.0 ] |
| sensorBandWidths | [20,20,20,20,20,20,40,40] |
| sensorNominalAltitudeInKM | 705 |
| sensorScanWidthInKM | 2801 |
| sensorResolutionInKM | 1 |
| sensorPlatform | "OrbView-2" |
| sensorPlatformType | "Polar-orbiting Satellite" |

Information about the time of the input data file:

| | |
|---|---|
| timeStart | Date and Time of first scan line. |
| timeStartYear | Year of first scan line. |
| timeStartDayofYear | Day of Year of first scan line. |
| timeStartTime | UTC Time of first scan line in milliseconds. |
| timeEnd | Date and Time of last scan line. |
| timeEndYear | Year of last scan line. |
| timeEndDayofYear | Day of Year of last scan line. |
| timeEndTime | UTC Time of last scan line in milliseconds |

Location Information of the input data file:

| | |
|---|---|
| localeUpperLeft | Location of pixel 1, line 1 |
| localeUpperRight | Location of pixel n, line 1 |
| localeLowerLeft | Location of pixel 1, line m |
| localeLowerRight | Location of pixel n, line m |
| localeNWCorner | Most Northern and Western point |
| localeNECorner | Most Northern and Eastern point |
| localeSWCorner | Most Southern and Western point |
| localeSECorner | Most Southern and Eastern point |

Note:

This does not represent the four corner points of the map projected imagery found in the file. These are representative of the input file prior to warping.

Information about input files:

| | |
|---|---|
| inputLevel1AFile | Name of input file. |
| inputMET1 | "CLIMATOLOGY.MET" |
| inputMET2 | set to NULL |
| inputMET3 | set to NULL |
| inputOZONE1 | "CLIMATOLOGY.OZONE" |
| inputOZONE2 | set to NULL |
| inputOZONE3 | set to NULL |
| inputCalibrationFile | "SEAWIFS_SENSOR_CAL.TBL-200104" |

#### 7.1.2. Data Sets:

A Gulf of Mexico Bio-Optical Data set contains 32 scientific data sets representing the 32 geophysical parameters mentioned above as well as an additional 4 datasets used for navigation (see below). These geophysical products are stored as signed 16-bit "chunked" compressed (deflate) Scientific Data Sets (SDS) measuring 2430 pixels wide and 1810 pixels deep.

Additionally, an empty "History" SDS was added, but unfortunately, was not properly implemented by the software.

##### 7.1.2.1. Data Set Attributes:

For each of the 32 geophysical scientific datasets the following attributes are attached.

| | |
|---|---|
| createTime | Time SDS was created |
| createSoftware | Name of executable that created file. |
| createPlatform | "i686-pc-linux-gnu" |
| productName | Name of product |
| productUnits | Units of data. |
| productScaling | "Linear" |
| scalingSlope | slope for the linear scaling. |
| scalingIntercept | intercept for the linear scaling. |
| productValidRanges | Min/Max of "expected" values. |
| productDataRanges | Min/Max of data within the "expected" values. |
| productActualRanges | Actual Min/Max of data including "outfliers" |

##### 7.1.2.2. Navigation:

The earth location information is appended as geographical locations (latitudes/longitudes) for given samples/lines overlaying the image. This information is stored in the following scientific data sets.

| | |
|---|---|
| CP_Pixels | 1-D Array of sample locations. |
| CP_Lines | 1-D Array of line locations. |
| CP_Latitudes | 2-D Array of latitudes at each pixel. |
| CP_Longitudes | 2-D Array of longitudes at each pixel. |

The map projection software uses the USGS General Cartographical Transformation Package (GCTP) and the parameters are given above. The control point information in the four scientific data sets are generated by the software as another means for navigation.

#### 7.1.2.3. File Naming Conventions:

The Gulf of Mexico Bio-Optical Data Sets have the following file nomenclature:
`SYYYYDDDHHMMSS.N3_CCCC_GOM`
This nomenclauture is very similiar to the standard SeaWiFS L1A file nomenclature. 'S' indicates the data set is "SeaWiFS". "YYYY" is a four-digit year of data set; "DDD" is a 3-digit day of year of data set. "HHMMSS" represents the hour, minute, and second of the first scan line of the input file. "N3" denotes the file is an NRL Level-3 type file. "CCCC" is the data type and is almost always "HNAV" which represents HRPT data collected by the NRL receiving station. An example is S2000045175943.N3_HNAV_GOM

Note: An NRL SeaWiFS data file which is designated as Level-3 uses a defination different from that of NASA. Here, NRL designates a Level-3 data set as a single pass that has been geometrically corrected only. It does not indicate a "binned" product.

## 8. Data Manipulations:

### 8.1. Data Processing Sequence:

The process of deriving accurate geophysical values from remote sensing radiance data is conceptually simple yet operationally complex. In principle, the instrument in space detects the intensity of light at various wavelengths of the electromagnetic spectrum. In the case of SeaWiFS, all of the wavelengths it detects are in the narrow segment of the spectrum that is visible to the human eye. The sole function of the instrument and its associated electronics is to quantify the light intensity, translate it into digital form, append data that allows the data to be navigated (i.e., determine the location on Earth from where the light originated), and send it to an Earth-based receiving station.

The remainder of the data analysis takes place on Earth. Algorithms developed on the basis of radiative transfer physics and both oceanographic and meteorological observation are employed to accurately extract the faint signal of backscattered light radiating from the ocean surface from the pervasive influence of scattered light in the atmosphere, an effect that is accentuated by the presence of atmospheric aerosol particles. The CZCS employed the assumption that no light radiated from the ocean surface at 670 nm, and thus all of the light detected was due to Rayleigh scattering from air molecules and aerosol scattering. SeaWiFS improves on this scheme by detecting light at 765 and 865 nm, as a small amount of light may actually radiate from the ocean at 670 nm. Furthermore, the atmospheric correction scheme used by SeaWiFS more accurately reproduces variable atmospheric conditions (Gordon and Wang 1994).

The assumption that the signal from the 765 and 865 channels is signly due to the atmosphere is disputed by the investigator due to the great number of negative remote sensing reflectance values in the coastal regions calculated from the above atmospheric correction algorithm. A scheme to iteratively correct for the very small amount of light present in these channels is used in the Gulf of Mexico Bio-Optical Data Set. This near-ir correction, however, does not completely correct the calculation of negative remote sensing reflectances.

Another algorithm which iterates on the 412 channel has been shown to correct the negative radiance problem. This algorithm attempts to reconstruct the spectrum by estimating what the 412 channel should produce based on the 555 and 670 channels and a bio-optical model. Both the 412 iteration and near-ir iteration algorithms were employed in this data set.

Once the reflectance signal has been corrected for atmospheric light scattering, the signal is then corrected for the solar zenith angle to derive remote sensing reflectance. Remote sensing reflectance radiances are subsequently used in algorithms to produce geophysical values. These algorithms were developed through oceanographic research into the optical characteristics of oceanic surface waters. As the most significant influences on the optical nature of oceanic waters are the presence of chlorophyll in phytoplankton and the presence of suspended particles, the algorithms use the water-leaving radiances to calculate the values of the related geophysical parameters. The geophysical parameters are calculated from the radiance values on a pixel-by-pixel basis, allowing the values to be mapped to Earth coordinates.

Several different methods have been employed to allow an accurate continuous assessment of instrument calibration. These methods were previously described in Section 5. The data analysis utilizes observations of the onboard solar diffuser and of the nearly-full moon for onboard instrument calibration. Data from the Marine Optical Buoy (MOBY) moored off of Lanai, Hawaii, is used to monitor the accuracy of "system calibration", which refers to the interaction of sensor data and scientific data processing to derive geophysical values that approximate reality.

### 8.2. Processing Steps:

SeaWiFS Level 0 data is digitized at 10 bits for transmission to ground stations. The primary data elements in Level 0 data are the raw radiance counts for all eight bands, accompanied by spacecraft and instrument telemetry. Processing to Level 1A appends calibration and navigation data to the file, as well as instrument and selected spacecraft telemetry. There are several different forms of Level 1A data: HRPT LAC, recorded LAC (which includes several types of calibration data), and GAC. A single GAC file consists of a swath data recorded from one north-to-south orbital pass, and constitutes one HDF file. A single HRPT file contains all of the scans received by the ground station while the satellite was above the station's receiving horizon. Recorded LAC scans, which are usually recorded for calibration and validation purposes as well as for regions of special research interest, contain the number of scan lines ordered by Mission Operations to cover the designated region.

Processing to Level 2 requires several additional steps. The data is navigated so that land masks may be correctly placed. Ancillary meteorological data and ozone data is used for atmospheric correction. The computational steps described earlier are employed to produce remote sensing reflectances and derived geophysical products. Each Level 2 data file is one HDF file, and corresponds exactly in temporal and spatial extent to the parent Level 1A file. Note that only Level 1A HRPT data is processed to Level 2.

The primary operation that is performed to create the Level 3 data products is the data being warped to the Gulf of Mexico map projection.

### 8.3. Limitations of the Data:

Similar to other optical remote sensing instruments, the Gulf of Mexico Bio-Optical data will be affected by the presence of clouds, particularly on a daily basis and sun glint.

## 9. Software:

### 9.1. Software Description

The software used to produce the Gulf of Mexico Bio-Optical Data Set is based on the developemental version of anly as of 31 August 1999. The program anly is the Level-2 processing software used by the SeaWiFS Project and is available through SeaDAS 3.3 (where it is called l2gen). The developmental version was made available to certain members of the Science Team.

This developmental program was further modified by NRL to include code for writing out the data sets described above. This software is included in the NRL Automated Processing System v2.3.

The following modifications were present in the developemental version of anly:

| | |
|---|---|
| 1 | Time dependent calibration file. |
| 2 | Seigel NIR correction. |
| 3 | Frouin white cap correction (new seawifswhite.cal file) |
| 4 | Option during aersol correction to use bands 6 and 8. |
| 5 | Option to force a particular aerosol model. |
| 6 | Arnone NIR correction algorithm. |
| 7 | Stumpf 412 iteration. |

Of these, the Gulf of Mexico Bio-Optical Data Set used 1, 3, 6, and 7.

More information can be found at the following web site: http://seawifs.gsfc.nasa.gov/~sbailey/wkshp_main.html

## 10. Data Access

The Gulf of Mexico Bio-Optical Data Set is split into two data bases. One data base contains the Daily Data Sets and the other contains the Browse images.

The Daily Data Base is located locally on the NRL file server 'thing'. The data is available to local scientists through the automount link "/rs/lvl3/seawifs/2.3/GulfOfMexico". The file structure under this is year followed by month (3-character abbreviation). The files are internally compressed and are readable by authorized users. Read them directly from the database.

The Browse Data Base is located locally on the NRL web server 'www7420'. They can be reached at this link:

`http://www7240.nrlssc.navy.mil/browse/lvl3/seawifs/2.3/GulfOfMexico/`

## 11. Output Products

The Gulf of Mexico Bio-Optical Data Set contains 32 ocean color products, several of them computed using several different algorithms. Part of the objectives of this data set is algorithm developement.

There are two types of products in the Gulf of Mexico Bio-Optical Data Set. The first are full resolution daily scenes warp to a map projection of the Gulf of Mexico. The second are several reduced images mainly used for image selection.

### 11.1. Daily Data Set:

Daily 1 km map projected images of thirty-two ocean color bio-optical products:

| |
|---|
| Remote Sensing Reflectances at 412, 443, 490, 510, 555, 670. |
| Chlorophyll-a concentration (Carder, SeaBAM, Stumpf). |
| Diffuse Attenuation at 532. |
| Beam Attenuation at 670. |
| Total Absorption at 412, 443, 490, 510, 555, 670 (Carder,Arnone). |
| Detris and Gelbstoff Absorption at 412, 443 (Carder,Stumpf). |
| Phytoplankton Absorption at 412, 443 (Carder,Stumpf). |
| Backscattering at 412, 555. (Carder,Arnone). |
| Albedo at 865 nm. |
| Quality Check flag |

The remote sensing reflectance values are derived by removing the atmospheric contamination from the top-of-the-atmosphere radiance as seen by the SeaWiFS instrument. This is based on the Gordon and Wang atmospheric algorithm with near-ir and 412 iteration schemes applied (see above).

The three cholophyll-a products are derived from the SeaWiFS Projects default algorithm which came out of the SeaBAM (also known as the OC2 algorithm); a semi-analytical algorithm from Ken Carder (v1.4); and the Gulf of Mexico regional algorithm from Rick Stumpf. The Stumpf algorithm is a reformulation of the OC2 algorithm to correct of the OC2 algorithm overestimation of the chlorophyll-a concentration in turbid coastal waters.

The diffuse attenuation algorithm is based on the ratio of the 490 to 555 channel (Mueller) rather than the default SeaWiFS Project algorithm which is based on the ratio of the 443 to 555.

Several of the inherenet optical products are derived from Ken Carder's semi-analytic algorithm. Another set are products of the 412 iteration scheme. A new algorithm by Arnone completes the optical set.

### 11.2. Browse Images:

Subsampled (every fifth pixel and every fifth line) Daily data for use in image selection. Daily browse images contain eleven products:

| |
|---|
| Chlorophyll-a concentration (SeaBAM, Stumpf). |
| Diffuse Attenuation at 532. |
| Backscattering at 555. (Carder,Arnone). |

Each browse image has four masks applied to it: land, cloud, atmospheric algorithm failures, and sunglint. Except for land, the masks are annotated on the browse image and are shown in varing shades of gray.

Additionally, each browse images contains the date and time of the image, a color bar with legend, coastline, and grids.

## 12. Known Problems.

1. The IOP products produced from Arnone and Carder have data values set for location where the remote sensing reflectance's were all zeros. These should have returned all zero's but did not.

## 13. References:


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